MASTER OF SCIENCE
IN
MODELING, VIRTUAL ENVIRONMENTS, AND SIMULATION

DISTANCE PERCEPTION AND VISUALIZATION USING VIRTUAL ENVIRONMENTS

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The studies in this thesis include experiments in training transfer, metric and visual feedback, field of view within the visual display, and cognitive relationships with distance perception. Participants were tested to show positive training transfer, retention of training, and organizational skills. Participants were trained to judge the distance perception in the in-depth plane, given a distance in a frontoparallel plane and also trained to judge perceived distances from themselves to an object. Experiment one shows that a positive training transfer exists from the virtual to the real world and visa versa. Experiments two and three show that perceptual feedback gives more information than metric feedback. Experiment four shows that between 30 – 60 degree geometric field of view setting should be used for optimal performance on distance estimation tasks using an HMD with 60-degree optical FOV. Experiment five shows that there is no correlation between how well participants organize symbols and how well they can be trained to judge distances. Experiments also confirm that as distances increased so did the amount of error.

DoD KEY TECHNOLOGY AREAS: Human Systems Interface, Manpower, Personnel, and Training, Modeling and Simulation

KEYWORDS: Distance Perception, Feedback, Human Factors, Human Error, Modeling, Manpower, Personnel and Training, Simulation, Training Transfer, Virtual Reality

THE ROLE OF PERSONALITY IN DETERMINING VARIABILITY IN EVALUATING EXPERTISE

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This research investigated how different experts in a single domain chose their individual subjective evaluation criteria of a highly aggregate task based upon their individual differences. The Conning Officer Virtual Environment (COVE) was utilized to provide a domain of experts and a subjectively evaluated task. One hundred sixteen expert shiphandlers were investigated to understand how their personality affects their evaluation of a novice performing an underway replenishment (UNREP). The experts were issued a survey that inventoried their personality, UNREP evaluation criteria, and shiphandling style. In general, the participant experts were lower in neuroticism and higher in extraversion and conscientiousness than the average adult. Extraversion appeared to be correlated with the expert's desire to use sensory input as a critical evaluation criterion (? = .18) while openness was correlated with analytical input (? = .16) and UNREP style (? = .16) as critical evaluation factors. Also correlated with UNREP style was

agreeableness (? = .16). Finally, the expert's level of conscientiousness correlated with the critical evaluation criteria of analytical input (? = .17) and sensory input (? = .39). Results from this research provide insight to the link between observed behavior and its subjective evaluation and will allow COVE's programmers to develop an Intelligent Tutoring System (ITS) that will customize the automated training process.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Manpower, Personnel, and Training, Modeling and Simulation

KEYWORDS: Shiphandling, Virtual Reality, Intelligent Tutoring Systems, Interactive Learning Environment, Virtual Environment, Surface Warfare, Computer Simulation, Underway Replenishment, Computer Graphics, Personality, Individual Differences, NEO-FFI, Five Factor Model

RE-PURPOSING COMMERCIAL ENTERTAINMENT SOFTWARE FOR MILITARY USE

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Virtual environments have achieved widespread use in the military in applications such as theater planning, training, and architectural walkthroughs. These applications are generally expensive and inflexible in design and implementation. Re-purposing these applications to meet the dynamic modeling and simulation needs of the military can be awkward or impossible.

Video games are designed to be both technologically advanced and flexible in design. We evaluated current games and modified Quake 3 Arena™ (Q3A) to serve as both an architectural walkthrough and a primitive team trainer. To accomplish this, a real Naval Postgraduate School building was incorporated into Q3A. The game's source code, characters and their behaviors, weapons models and characteristics, and overall gameplay was modified.

By re-purposing commercial entertainment software, a viable military virtual environment application was produced that is less expensive yet arguably as engaging as current computer-based options. This application was created in approximately 300 man-hours with a cost of $6780 (including hardware) -far less than the development time and cost of similar military virtual environment applications. Game evaluations included in this thesis facilitate and inform similar modification efforts by highlighting entertainment technology available in the year 2000 game market.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation

KEYWORDS: Modeling and Simulation, Software Re-Purposing, Video Games, Entertainment Technology, Architectural Walkthrough, Game Modification

FITTING FIREPOWER SCORE MODELS TO THE BATTLE OF KURSK DATA

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This thesis applies several Firepower Score attrition algorithms to real data. These algorithms are used in highly aggregated combat models to predict attrition and movement rates. The quality of the available historical data for validation of attrition models is poor. Most accessible battle data contain only starting

sizes and casualties, sometimes only for one side. A detailed database of the Battle of Kursk of World War II, the largest tank battle in history, has recently been developed by Dupuy Institute (TDI). The data is two-sided, time phased (daily), highly detailed, and covers 15 days of the campaign. According to combat engagement intensity, three different data sets are extracted from the Battle of Kursk data. RAND's Situational Force Scoring, Dupuy's QJM and the ATLAS ground attrition algorithms are applied to these data sets. Fitted versus actual personnel and weapon losses are analyzed for the different approaches and data sets. None of the models fits better in all cases. In all of the models and for both sides, the Fighting Combat Unit Data set gives the best fit. All the models tend to overestimates battle casualties, particularly for the Germans.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Combat Modeling, Simulation, Attrition, Validation, Firepower Scores, Battle of Kursk

COMPARISON OF PERFORMANCE MEASURES IN THE VIRTUAL ENVIRONMENT AND REAL WORLD LAND NAVIGATION TASKS

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Spatial knowledge acquisition is an integral part of navigation related studies. With the improvement of technology, the researchers gained the capability of testing the spatial ability in a virtual world as well. However, little research has been conducted to understand whether VE performance can predict Real World performance or not and amongst the measures used what measures are most predictive.

This thesis research addresses the validity of performance measures used in virtual and real environments. Ten subjects have participated in two experiments. The first experiment was a navigation task in a building type virtual environment. With some modifications, Hermann Hall model was used for this experiment. The second experiment was a navigation task in a real building. For this experiment Middle East school in DLI was used. Measures of landmark, survey and route knowledge were taken for each participant.

The results did not suggest a correlation in overall performance measures. However a correlation is observed in the performance for the landmark knowledge. The acquisition of survey knowledge by time is also seen in the results of the study.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Virtual Environments, Land Navigation, Spatial Knowledge

3D VISUALIZATION OF THEATER-LEVEL RADIO COMMUNICATIONS USING A NETWORKED VIRTUAL ENVIRONMENT

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The military is heavily reliant on the transfer of information among various networks in day-to-day operations. Radio-based communications networks that support this volume of information are complex, difficult to manage, and change frequently. Communications network planners need a way to clearly visualize and communicate mobile operational network capabilities, particularly to network users.

By using the DIS-Java-VRML simulation and modeling toolkit, visualizations of radio-frequency energy and radio path-profiling data can be quickly generated as 3D models. These animated 3D

visualizations can be loaded into a networked virtual environment, so that communications planners can detect a variety of problems such as radio frequency interference and gaps in coverage. Planners can also brief senior staff, plan within their own staff, and collaborate with communications staff planners in distant locations using such virtual environments.

DIS-Java-VRML visualization tools can provide a clear picture of the battlespace with respect to the deployed communications architecture. The prototypes presented in this thesis demonstrate the ability to generate a shared visualization that can show a radio communications network in 3D. Such dynamic visualizations increase communications planning information bandwidth and yield more intuitive ways of presenting information to users. Higher information density in a more intuitive format enables better understanding with quicker reaction times. This thesis and the visualization tool discussed provide the foundation for fundamental improvements in visualizing radio communications environments.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Command, Control and Communications, Computing and Software, Human Systems Interface, Sensors, Modeling and Simulation

KEYWORDS: Virtual Environments, Visual Simulation, Signal Planning, VRML, Java, DIS-Java-VRML, X3D

INTEGRATING REALISTIC HUMAN GROUP BEHAVIORS INTO A NETWORKED 3D VIRTUAL ENVIRONMENT

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Virtual humans operating inside large-scale virtual environments (VE) are typically controlled as single entities. Coordination of group activity and movement is usually the responsibility of their "real world" human controllers. Georeferencing coordinate systems, single-precision versus double-precision number representation and network delay requirements make group operations difficult. Mounting multiple humans inside shared or single vehicles, (i.e., air-assault operations, mechanized infantry operations, or small boat/riverine operations) with high fidelity is often impossible.

The approach taken in this thesis is to re-engineer the DIS-Java-VRML Capture the Flag game geolocated at Fort Irwin, California to allow the inclusion of human entities. Human operators are given the capability of aggregating or mounting nonhuman entities for coordinated actions. Additionally, rapid content creation of human entities is addressed through the development of a native tag set for the Humanoid Animation (H-Anim) 1.1 Specification in Extensible 3D (X3D). Conventions are demonstrated for integrating the DIS-Java-VRML and H-Anim draft standards using either VRML97 or X3D encodings.

The result of this work is an interface to aggregate and control articulated humans using an existing model with a standardized motion library in a networked virtual environment. Virtual human avatars can be mounted and unmounted from aggregation entities. Simple demonstration examples show coordinated tactical maneuver among multiple humans with and without vehicles. Live 3D visualization of animated humanoids on realistic terrain is then portrayed inside freely available web browsers.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software, Battlespace Environments, Command, Control and Communications, Human Systems Interface

KEYWORDS: Virtual Environments, Humanoid Animation 1.1 Specification, Distributed Interactive Simulation, 3D, Aggregation, Mounting Human Entities, Virtual Humans, Avatars, X3D, X3d-Edit, VRML, Java, DIS-Java-VRML, Web3D Consortium

MODELING HUMAN AND ORGANIZATIONAL BEHAVIOR USING A RELATION-CENTRIC MULTI-AGENT SYSTEM DESIGN PARADIGM

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Today's modeling and simulation communities are being challenged to create rich, detailed models incorporating human decision making and organizational behavior. Recent advances in distributed artificial intelligence and complex systems theory have demonstrated that such ill-defined problems can be effectively modeled with agent-based simulation techniques using multiple, autonomous, adaptive entities. RELATE, a relation-centric design paradigm for multi-agent systems (MAS), is presented to assist developers incorporate MAS solutions into their simulations. RELATE focuses the designer on six key concepts of MAS simulations: relationships, environment, laws, agents, things, and effectors. A library of Java classes is presented which enables the user to rapidly prototype an agent-based simulation. This library utilizes the Java programming language to support cross-platform and web based designs. It includes a concise users manual and clear documentation in HTML format. Two reference cases are provided that allow for easy code reuse and modification. Finally, an existing networked DIS-JAVA-VRML simulation was modified to demonstrate the ability to utilize the RELATE library to add agents to existing applications. LCDR Kim Roddy focused on the development and refinement of the RELATE design paradigm, while LT Mike Dickson focused on the actual Java implementation. Joint work was conducted on all research and reference cases.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Multi-Agent System, MAS, Human and Organizational Behavior, Agent-Based Simulation, Adaptive Agents, Autonomous Agents, Relationship, RELATE, Architecture

REPRESENTING TACTICAL LAND NAVIGATION EXPERTISE

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Tactical land navigation is a very important, but extremely difficult task performed daily by small unit leaders. In an effort to find ways to develop expertise more efficiently, a detailed description of expert performance is presented and contrasted with novice and intermediate performance. This definition fits the Recognition Primed Decision model of human cognitive behavior. Then, through use of the Critical Decision Method of knowledge elicitation, interviews with experts at the U. S. Army Special Forces Qualification Course formed the basis of a detailed cognitive model of expert tactical land navigation. Four important characteristics of experts emerge: (1) they rely on high-fidelity mental maps; (2) they blend multiple cues; (3) they adjust and recalibrate tools dynamically; and (4) they visualize spatial information. Finally, a multi-agent system computationally represents the route planning portion of the performance model.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Computing and Software, Human Systems Interface, Ground Vehicles, Modeling and Simulation

KEYWORDS: Agent Based Modeling, Land Navigation, Multi-Agent System, Human Performance Modeling

DYNAMIC EXPLORATION OF HELICOPTER RECONNAISSANCE THROUGH AGENT-BASED MODELING

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This thesis uses Multi-Agent System modeling to develop a simulation of tactical helicopter performance while conducting armed reconnaissance. It focuses on creating a model to support planning for the Test and Evaluation phase of the Comanche helicopter acquisition cycle. The model serves as an initial simulation laboratory for scenario planning, requirements forecasting, and platform comparison analyses.

The model implements adaptive tactical movement with agent sensory and weaponry system characteristics. Agents are able to determine their movement direction and paths based on their perceived environment, attributes, and movement personalities. The model incorporates a three-dimensional aspect to properly simulate aerial reconnaissance. An integrated Graphical User Interface enables the user to create environments, instantiate agent propensities and attributes, set simulation parameters, and analyze statistical output.

The resulting model demonstrates the ability to represent helicopter reconnaissance behavior. It captures simulation summary statistics that illustrate enemy performance, helicopter performance, and logistical requirements. The model establishes an initial simulation tool to further explore Comanche operational requirements and planning for its Test and Evaluation phase.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Battlespace Environments, Computing and Software, Conventional Weapons, Human Systems Interface, Sensors, Ground Vehicles, Manufacturing Science and Technology (MS&T), Modeling and Simulation

KEYWORDS: Multi-Agent System, Agent-Based Modeling, Helicopter Reconnaissance, Comanche, Adaptive Behavior, Modeling and Simulation